

We Claim:

1. A compact and efficient fuel processor operating at pressures higher than one atmosphere and temperatures above 300°C for reforming distillate hydrocarbon fuels containing sulfur to obtain high quality hydrogen product, comprising:

a separation assembly for converting and separating a sulfur-containing distillate fuel feed into an aliphatics-rich and sulfur-depleted gas stream and an aromatics-rich and sulfur-rich liquid stream;

a desulfurization assembly for receiving the aliphatics-rich and sulfur-depleted gas stream exiting the separation assembly and for removing hydrogen sulfide therefrom to output desulfurized gas;

a combustion assembly for receiving said aromatics-rich and sulfur-rich liquid stream exiting the separation assembly and for combusting said liquid stream with air to yield process heat; and

a reforming assembly in which process heat from the combustion assembly is used to generate steam and convert the desulfurized gas exiting the desulfurization assembly to a hydrogen-rich stream.

2. The fuel processor as set forth in claim 1, wherein said separation assembly includes:

a fuel vaporizer for generating a vaporized and superheated fuel stream from incoming distillate fuel;

a catalytic cracking reactor for receiving said fuel stream from said fuel vaporizer and selectively cracking an aliphatic content of said fuel stream to light hydrocarbon gases while converting any organosulfur species to hydrogen sulfide; and

a gas-liquid separator receiving and separating an output from said cracking reactor into a gas stream directed to said desulfurization assembly and a condensed liquid stream directed to said combustion assembly.

5 3. The fuel processor as set forth in claim 2, wherein said cracking reactor includes a catalyst that provides high activity for cracking the aliphatic content, high activity for conversion of the organosulfur species to hydrogen sulfide, and low selectivity for coke formation.

10 4. The fuel processor as set forth in claim 3, wherein the catalyst includes manganese on alumina with 10-15 weight percent loading.

15 5. The fuel processor as set forth in claim 2, wherein said combustion assembly provides heat to said separation assembly for said vaporization and superheating by said vaporizer and for said catalytic cracking by said cracking reactor.

 6. The fuel processor as set forth in claim 2, wherein said separation assembly further includes:

 a fractionator for receiving the vaporized and superheated fuel stream and separating said fuel stream into a heavy liquid residue stream and a light vapor stream, said
20 vapor stream being directed to the cracking reactor and said residue stream joining said condensed liquid stream output by said gas-liquid separator.

7. The fuel processor as set forth in claim 2, wherein said desulfurization assembly includes:

a high temperature adsorber for conducting a first stage of hydrogen sulfide adsorption on said gas stream to produce a partially desulfurized gas stream; and

5 a low temperature adsorber for conducting a second stage of hydrogen sulfide adsorption on said partially desulfurized gas stream.

8. The fuel processor as set forth in claim 1, wherein said steam reforming assembly includes:

10 a steam generator for producing a steam stream; and

a catalytic steam reforming reactor for receiving said steam stream and a desulfurized hydrocarbon gas stream from said desulfurizing assembly, and for generating therefrom a product stream that is rich in hydrogen.

15 9. The fuel processor as set forth in claim 8, wherein said steam reforming assembly further includes:

a hydrogen purifier coupled to said catalytic steam reforming reactor for separating said product stream into a hydrogen-rich product stream and a hydrogen-depleted reject stream.

20 10. The fuel processor as set forth in claim 9, wherein said steam reforming assembly further includes a water recovery component coupled to said catalytic steam reforming reactor for recovering excess steam therefrom and directing such excess steam to said steam generator.

11. The fuel processor as set forth in claim 2, wherein said combustion assembly includes:

a combustion fuel reservoir coupled to said separation assembly for receiving the
5 condensed liquid stream; and

a combustion reactor for combusting a mixture of fuel from said fuel reservoir and an air feed stream to provide heat to said separation assembly for said vaporization and superheating by said vaporizer and for said catalytic cracking by said cracking reactor.

10 12. The fuel processor as set forth in claim 11, wherein said combustion reactor includes a catalyst of copper/potassium/vanadium on alumina with 2-20 weight percent loading.

13. The fuel processor as set forth in claim 11, wherein said combustion assembly

and Fuel Cell exhaust
further includes a water recovery component coupled to said combustion reactor for recovering
15 water into a condensed liquid stream that is directed to said steam reforming assembly.

14. A compact and efficient fuel processor comprising:

a separation assembly for converting and separating a sulfur-containing distillate fuel feed into an aliphatics-rich/sulfur-depleted gas stream and an aromatics-rich and sulfur-rich
20 liquid stream, said separation assembly including a fuel vaporizer, a catalytic cracking reactor downstream of said fuel vaporizer, and a gas-liquid separator downstream of said catalytic cracking reactor, said gas-liquid separator outputting a gas stream and a liquid stream;

a desulfurization assembly having a high temperature adsorber and a low temperature adsorber arranged in series for removing hydrogen sulfide from the gas stream exiting the separation assembly to output desulfurized gas;

5 a combustion assembly including a combustion fuel reservoir and a combustion reactor in which the liquid stream exiting the separation assembly is combusted with air to yield process heat; and

a steam reforming assembly for generating steam using said process heat and for converting, using a catalytic steam reforming reactor, the desulfurized gas exiting the desulfurization assembly to a hydrogen-rich stream;

10 said fuel processor operating at pressures higher than one atmosphere and temperatures above 300°C for reforming distillate hydrocarbon fuels containing sulfur to obtain high quality hydrogen product.

15 15. The fuel processor as set forth in claim 14, wherein said catalytic cracking reactor receives a vaporized and superheated fuel stream from said fuel vaporizer and selectively cracks an aliphatic content of said fuel stream to light hydrocarbon gases while converting any organosulfur species to hydrogen sulfide.

20 16. The fuel processor as set forth in claim 15, wherein said catalytic cracking reactor includes a catalyst of manganese on alumina with 10-15 weight percent loading.

17. The fuel processor as set forth in claim 15, wherein said separation assembly further includes a fractionator receiving the vaporized and superheated fuel stream from said fuel

vaporizer and separating said fuel stream into a heavy liquid residue stream and a light vapor stream, said vapor stream being directed to the cracking reactor and said residue stream joining the liquid stream output by said gas-liquid separator.

5 18. The fuel processor as set forth in claim 14, wherein said steam reforming assembly further includes a hydrogen purifier coupled to said steam reforming reactor for separating said hydrogen-rich stream into a hydrogen-rich product stream and a hydrogen-depleted reject stream.

10 19. The fuel processor as set forth in claim 14, wherein each of said steam reforming assembly and said combustion assembly further includes a water recovery component.

20. The fuel processor as set forth in claim 14, wherein said combustion reactor includes a catalyst of copper/potassium/vanadium on alumina with 2-20 weight percent loading.

15 21. A method using a fuel processor for processing fuel for reforming distillate hydrocarbon fuels containing sulfur to obtain high quality hydrogen product, the method comprising the steps of:

 converting and separating a sulfur-containing distillate fuel feed into an aliphatics-rich/sulfur-depleted gas stream, and an aromatics-rich and sulfur-rich liquid stream;

20 removing hydrogen sulfide from said gas stream through high temperature

adsorption followed by low temperature ^dadsorption to generate desulfurized gas;

combusting said liquid stream with air to yield process heat;

generating steam using said process heat; and

converting, using said steam, the desulfurized gas to a hydrogen-rich stream.

22. The method as set forth in claim 21, wherein the step of converting and separating includes the steps of:

5 generating a vaporized and superheated fuel stream;
 selectively cracking an aliphatic content of said fuel stream to light hydrocarbon
gases while converting any organosulfur species to hydrogen sulfide to generate an output; and
 separating said output into said gas stream and said liquid stream.

10 23. The method as set forth in claim 22, further comprising after the step of generating,
the step of separating the vaporized and superheated fuel stream into a heavy liquid residue
stream and a light vapor stream, said light vapor stream proceeding to be selectively cracked and
said heavy liquid residue stream being directed into said liquid stream.

15 24. The method as set forth in claim 22, wherein the step of selectively cracking is
performed using a catalyst of manganese on alumina with 10-15 weight percent loading.

20 25. The method as set forth in claim 22, wherein the process heat generated during the
step of combusting is fed back and used for the steps of generating the vaporized and
superheated fuel stream and selectively cracking said fuel stream.